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NOUVELLE SÉRIE

1944

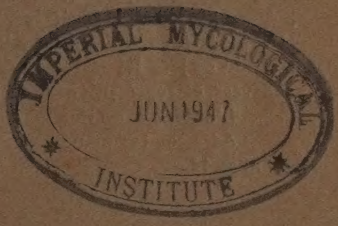

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TABLE DES MATIÈRES

ASTRONOMIE Pages

B. V. Kukarkin. Optical Depth of Selective Absorption of an Elementary Dark Nebula 243

G. A. Shajn, Member of the Academy. Emission Lines of FeII in Spectra of Long-Period Variables 245

MÉCANIQUE

V. V. Dobronravov. On the Invariance of the Hamilton-Jacobi Equation in Quasi-Coordinates 249

PHYSIQUE MATHÉMATIQUE

I. S. Koukless. Sur deux groupes fondamentaux de points singuliers 253

PHYSIQUE

F. A. Korolev and G. I. Pokrovsky. Directional Effect of Explosion Studied by Optical Method 256

N. A. Perfilov. Destruction of Latent Image of α-Particle Tracks in Photographic Layer 258

PHYSIQUE DU GLOBE

S. S. Kovner. On the Theory of Thermal Prospecting. Artinskian Massif as Revealed on the Slope of Gravitation Maximum 262

CHIMIE PHYSIQUE

S. B. Ratner. Some Measurements of Detonation Velocity of Methylnitrate . . 265

GÉOLOGIE

B. P. Krotov. On the Problem of the Post-Palaeogene Uplifts on the Eastern Slope of the Urals 268
E. K. Lazarenko. On the Hydrothermal Formations of the Korobkov Area of the Kursk Magnetic Anomaly 271
V. K. Monich. On the Age of the Epoch of Completed Mineralization in the Sarala Gold-Ore Deposit (Siberia, Kuznetsk Alatau) 274

PHYSIOLOGIE VÉGÉTALE

N. A. Maximov, Corresponding Member of the Academy, and **L. V. Mozhaeva.** Age Variations in the Colloid-Chemical Properties of Protoplasm of Vegetable Cells. II. Variations in Permeability and Viscosity in the Leaf Cells of Broad-Beans and Oats 277

Édition de l'Académie des Sciences de l'URSS
Moscou 1944

Comptes Rendus (Doklady) de l'Académie des Sciences de l'URSS
1944. Volume XLII, № 6

ASTRONOMY

OPTICAL DEPTH OF SELECTIVE ABSORPTION OF AN ELEMENTARY DARK NEBULA

By B. V. KUKARKIN

(Communicated by G. A. Shajn, Member of the Academy, 20.X.1943)

It may be considered as safely established that the absorption of light in the interstellar space is due to the presence of discrete dark nebulae. The density of those nebulae attains its maximum value in the plane of the Galaxy, and decreases with distance. Light rays from the objects situated outside the layer of dark nebulae (all extragalactic stellar systems, as well as globular clusters and separate stars with sufficiently great z-coordinates) will experience absorption (both general and selective) proportional to the number of average elementary nebulae lying on their way. Fluctuations in the number of elementary nebulae that lie on the way of light rays emitted by separate objects, will result in a fluctuation of their colour excesses. In case there is no natural dispersion of normal colours in the objects investigated, while the measurements of their colour excesses involve some error, the mean quadratic deviation of colour excesses will take the form

$$\sigma = \sqrt{n}\mu$$

where n is the number of elementary nebulae, and μ is the average optical depth of selective absorption of one elementary nebula. It is obvious that $n\mu$ is nothing else than the optical depth of the selective absorption of the whole absorbing layer. The investigation of the colour excesses of extragalactic stellar systems carried out on the basis of their colour measurements, as made by Stebbins and Whitford ([1]), leads to the following expression for the magnitude of $n\mu$ in the system of colours c_2 (its relation to other systems will be discussed below):

$$n\mu = 0^m.024 \csc b$$

where b is the galactic latitude. Consequently

$$\sigma^2 = 0^m.024\ \mu \csc b.$$

As a matter of fact, however, the mean quadratic deviation of colour excesses σ' is dependent not only on the fluctuations in the number of elementary dark nebulae, but also on the inaccuracy of the measurements and on natural fluctuations of the normal colours of the objects investigated;

$$\sigma'^2 = \varepsilon^2 + \sigma^2$$

where ε^2 is the mean quadratic deviation due to the causes just mentioned, while σ^2 keeps its former value. Consequently

$$\sigma'^2 = \varepsilon^2 + 0^m.024\ \mu \csc b. \qquad (1)$$

Under ideal conditions, the number of objects being large enough, their colour characteristics may be classed into several groups according to galactic latitude

and, after having obtained several conditional equations of the type (1), the value of ε^2 and μ might bb calculated by the method of least squares. However, the number of objects is no large one and the two unknowns defy any safe definition. It is therefore more convenient to build a single conditional equation of the form (1), assuming ε^2 to be known after the inner similarity of separate measurements.

In their papers cived above, Stebbins and Whitford (1) give the colours of 112 extra-galactic nebulae. The colours of three irregular nebulae and the colour of NGC 4273 have not been taken into account as being obviously anomalous. The colours of 108 nebulae have thus been made use of. Normal colours were adopted according to the type of nebula (see table).

Type of nebula	Normal colour
E	+0.09
Sa, SBa	+0.07
Sab	+0.06
Sb, SBb	+0.06
Sbc	0.00
Sc, SBc	−0.06

The deviations of the colours observed from these normal values were considered as colour excesses. The standard deviation σ'^2 has been computed from the mean value of the colour excess for all 108 objects. It has been found to be equal to 0.005448. According to the data by Stebbins and Whitford (1), $\varepsilon^2 = 0.004006$ (for the whole group of objects). By subtracting it from the value of σ'^2, we obtain

$$\sigma^2 = 0.001442.$$

The mean value of csc $b = 1.965$, hence $\mu = 0^m.030$ in the colour system c_2.

The colour excesses of globular stellar clusters with coordinates greater than 1000 parsec, as observed by Stebbins, Huffer and Whitford (2), were investigated in an analogous way. As a result there was obtained $\mu = 0^m.025$ within the same colour system.

Finally, 26 B-stars with z-coordinates larger than 300 parsec were treated in the same way. The colour excesses were taken from the author's general star colour catalogue (only determinations made by means of a potassium photocell were used). In the same system c_2 $\mu = 0^m.020$.

Attributing to the values obtained a weight corresponding to 3, 2 or 1 (in accordance with the number of objects), the ultimate value of the optical depth of selective absorption of an elementary fine nebula is found to be $\mu = 0^m.027$.

Stebbin's system of colour excess c_2 is connected with his system c_1 by the proportionality coefficient 1.682. According to Flor, in the international photographical system of stellar magnitudes, system c_1 is connected with total light absorption by the proportionality coefficient 7.5. Accordingly, the proportionality coefficient between the total photographical absorption and the selective absorption in the system c_1 makes up 12.5. The optical depth τ of the elementary dark nebula in photographical rays thus assumes the value

$$\tau = 0^m.027 \times 12.5 = 0^m.34$$

which is in fair agreement with the conclusion arrived at by Ambarzumian (3) on the ground of his study of the fluctuations in the number of extra-galactic nebulae at equal galactic latitudes.

Sternberg Astronomical Institute.

Received
20. X. 1943.

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Comptes Rendus (Doklady) de l'Académie des Sciences de l'URSS
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ASTRONOMY

EMISSION LINES OF FeII IN SPECTRA OF LONG-PERIOD VARIABLES

By G. A. SHAJN, Member of the Academy

In the spectra of the stars Me the intensities of hydrogen emission lines have long been known to display some very peculiar anomalies. With regard to FeI emission lines our information on the subject of intensity anomalies is very scarce. And in the case of FeII lines it remains even uncertain whether there are any anoma-

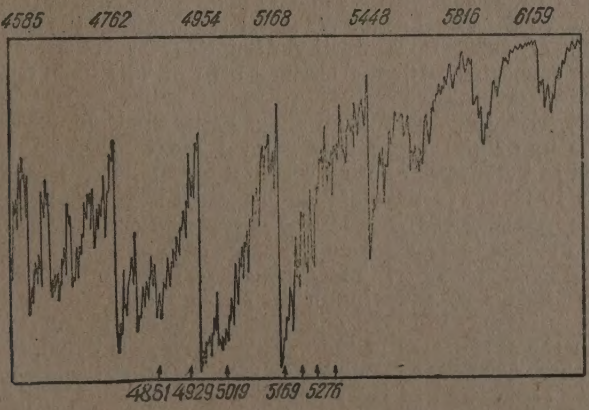

Fig. 1

lies at all. By endeavouring to disclose the general nature of these anomalies and to interpret them properly within the frame of a single hypothesis, we are likely to find a clue for the understanding of the complicated processes that take place in the atmospheres of these stars, and perhaps even to get at the very mechanism underlying the formation of emission lines. Of much importance is also to prove that the different ions and atoms do or do not travel at equal radial velocities; this point in our case is connected with the question as to their effective level in the atmosphere, in particular, for FeII, FeI and H.

A thorough investigation of the FeII line intensities, mainly in the spectrum o Ceti, led to the discovery of several conspicuous anomalies. Particularly remarkable is the nearly total absence of FeII emission lines in the green region of the spectrum of Me stars. We are lacking here the lines 4924, 5018, 5169, 5276 and 5316, which in the laboratory and in the spectra of other celestial bodies are scarcely fainter than 4233. Of these lines only very seldom did I observe 4924, and it seemed to be stronger on those spectrograms on which Hβ was the most strong.

A portion of a photomicrograph of the M5 spectrum is given in Fig. 1. In the

above-mentioned region the position of the lines we are interested in is indicated by arrows. It may be seen that all emission lines lie within strong absorption bands of TiO [α(5.3), α(2.1), α(1.0), α(0.0), α(3.3) and others] and it appears that for 4924 this effect is expressed the most weakly. The probable cause of this anomaly is that in certain frequencies, especially in 5018 and 5169, the radiation of FeII ions is hindered on its way out by absorption in the TiO molecules. A similar reason was formerly put forward to account for the anomaly in the intensity of hydrogen lines (1). From this it may be inferred that the emitting H atoms and FeII ions are at least not localized in the upper shell of the atmosphere of Me stars, and so in this respect there is no analogy with new, new-like or Be stars. Now it is of interest to know whether the behaviour of other FeII lines is in harmony with the result. We shall first consider those FeII lines which in other objects are, as a rule, scarcely weaker than the 4233 line. These lines are 4352. 4508, 4522, 4549 and 4584. Of them the 4508 and 4549 lines are not observed in Me spectra at all, and the lines 4584 and 4352 are observed very rarely, and then only as faint lines. Contrary to this, the line 4522 is observed often as a rather strong line. All that may be looked upon as an anomaly compared to what we have in the laboratory and in other celestial objects. For 4584, 4549, 4508 and 4352 the anomaly may be explained by the influence of the bands TiO α(3.0) Ra, α(7.3) Rc, α(6.2) Rc and α(7.2) Rc. In the case of 4352 one may also suppose the low-temperature line CrI 4351.77 to play a substantial part. But the presence of 4352 in the Me spectra is doubtful and so is its identification with FeII. Neither may the rather strong line 4521.4 observed in Me spectra be properly identified with FeII 4522.6. This line is notably stronger than FeII 4233. Whatever the origin of the line observed in the neighbourhood of 4522, it is worthy of notice for its considerable strength which may be connected with the absence here of TiO band [the next is α(6.2) Rc 4506].

Finally, we have to point out an anomaly in the lines 4233, 4179 and 4173, for which the upper and lower energy level are nearly equal. While in the laboratory and in the spectra of other celestial objects the intensity ratio of these lines is about 10 : 8 : 5, in the stars Me (o Ceti) it is 10 : 20 : 8, respectively (in both cases the intensity of the 4233 line is arbitrarily put at 10). Of these three lines the 4179 appears to be free from any influence and 4173 is possibly influenced in a slight degree by a very faint TiO band α(7.1) Ra. As for the line FeII 4233, it is probably affected by the wing of the strong resonance line CaI 4226 and is also under the influence of the low-temperature line FeI 4232.8 (the latter effect is apparent from the asymmetry of the emission line FeII 4233).

We refrain here from considering the fainter FeII lines: they may escape observation simply on account of their faintness and not necessarily because of the screening effect. However, the consideration of all stronger FeII lines, as has been shown above, brings out a series of anomalies which may be explained satisfactorily in terms of the screening hypothesis. This will be equivalent to the assumption that the mean effective level of the emitting ions is lower, or, at least, not higher, than that of the absorbing molecules and atoms which are TiO, CaI and FeI in our case. The radiation of FeII ions is weakened in such frequencies as happen closely to correspond to certain absorption frequencies for TiO, CaI and FeI.

A strong argument in favour of the hypothesis under consideration is derived from a comparison of the behaviour of FeII lines in the spectra of Me and Se stars. In the latter the TiO bands are known to be very faint or even absent. Unfortunately, the material secured by observations at Simeiz (R. Gemin, R. Andr. and others) and elsewhere (Merrill) is very poor. There is no sufficient evidence to draw the conclusion that the anomaly in 4233 : 4179 does take place in the Se stars also. On the other hand, one may point out here the presence of the emission lines FeII 4584, 4924, 5018 and possibly 4549, which are just the lines that are invisible or barely visible in Me spectra, owing, it seems, to the screening effect of the TiO bands. It may as well be remarked that 4352 is much stronger in Se than in Me spectra. Irrespective of whether this line is or is not due to FeII, its strengthening in Se appears to be connected with the weakening or

absence of the α(7.2.) Rc band. All of this is in line with the fact that the Balmer decrement $H_\beta : H_\gamma : H_\delta$ is nearly normal in Se, whereas in Me, especially in later subdivisions, the anomaly with regard to H is very strong.

We have strong reason to suppose that at least near the epoch of Max. the matter responsible for the emission lines moves radially outward, and in this case the difference in the radial velocities of different atoms and ions will apparently mean the difference in the effective level for them in the atmosphere. It is customary to consider the radial velocities for H and FeI as equal. And for FeII lines a positive shift of about 0.09 Å with respect to hydrogen and low-temperature emission lines was reported in o Ceti by Joy ([2]). The importance of this statement is obvious.

It is only for o Ceti that we have sufficient data on individual lines (Mt Wilson and Simeiz). What is given below are deviations from the laboratory values of λ for FeII or, in other words, the deviations for FeII relatively to H and FeI.

λ (laboratory)	Mt Wilson (Joy)	Simeiz (author)	Weight
4138.42	0.17 Å	0.21 Å	2
4173.47	0.00	0.01	1
4178.86	—0.04	—0.06	2
4233.16	0.17	0.15	4
4583.84	0.04	—	1
4923.91	—0.12	—0.09 ?	—
5018.43	0.01	—	—

The last two lines are discarded by Joy, and his conclusion as to the positive shift of FeII is practically based on the 4138 and 4233 lines. The observations made at Simeiz likewise testify to the presence of a large positive shift in the case of these lines. Yet, there are weighty arguments against the identification of the first line with FeII: 1) This line has never been observed in other celestial objects (chromosphere, *Novae*, Be, etc)., whereas all the other lines of FeII mentioned above are easily seen. 2) Nor was this line observed in the laboratory, and its λ was computed from the known terms. Of the other analogous lines predicted no one was observed in the laboratory or in the spectra of celestial objects. 3) 4138 is a very strong line in Me, at any rate much stronger than 4233. As to the line.4233 it may be remarked that at a distance of about 0.15 Å (after allowance for the usual shift of emission lines) there is a strong low-temperature absorption line FeI 4232.77 which may affect the position of the line FeII 4233. In fact, even at moderate dispersion the line 4233 appears narrower than the other FeII emission lines, and displays an obvious asymmetry on the large scale spectrogram of o Ceti reproduced in Adams' paper ([3]). From all of this we are bound to conclude that there is no reason to speak of any difference between the radial velocities of the FeII ions and the atoms of H and FeI. It will, however, be shown in a later communication that this conclusion does not necessarily apply to more distant phases.

What may be argued from the fact of equal radial velocity and of more or less equal screening effect for H, FeI and FeII is that at least about Max. the emitting atoms and ions in question are nearly in the same layer which in any case is not higher than the layers responsible for the absorption spectrum.

Since, judging by the *K*-term and the velocity difference between the emission and absorption lines, the emission matter is in radial motion outward, we may expect the screening effect to vary with the phase. This may be linked up either with the change of the number of absorbing molecules and atoms as a function of *T* and *P*, or with the change of the mean level of the emission matter relatively to that of the absorbing matter. It will be shown elsewhere that the former effect is small compared to the latter, so that the study of the variation of the anomaly with the phase is serviceable as a basis for our judgment about the change of the relative level of the matter responsible for the emission lines. Of the available data the

most numerous refer to the lines FeII 4233, 4179 and 4173. When we had them worked up using also Joy's estimates (2), we were able indeed to discover a quite appreciable variation with the phase in the relative intensities of these three lines. Smoothed values for the intensity ratio between 4233 and 4179 are represented graphically in Fig. 2. Though we have here to deal with estimates instead of measured intensities, yet the reality of the decrease of anomaly with advancing phase may

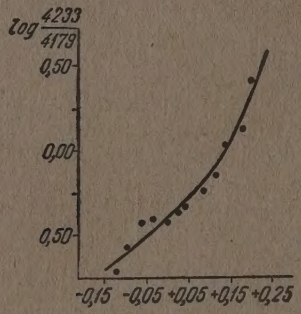

Fig. 2

hardly be called in question. Eventually the intensity ratio is likely to become normal. This may possibly be interpreted to mean that the relative level of the emitting FeII ions is subject to more or less continuous change with the advancing phase, with the result that in the distant phases the level of these ions in the atmosphere is generally much higher than the mean level of absorbing atoms and molecules. This and the fact that at least about Max. the FeII ions and atoms of H and FeI are not separated, but rather lie in the same level (probably in the lower one), throws an interesting light on the processes taking place in the atmospheres of Me stars. We will discuss the problem elsewhere in a more general form extending it to different elements.

Simeiz, Abastumani.

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MECHANICS

ON THE INVARIANCE OF THE HAMILTON-JACOBI EQUATION IN QUASI-COORDINATES

By V. V. DOBRONRAVOV

(Communicated by A. N. Kolmogoroff, Member of the Academy, 9.IX.1943)

1. The development of the geometry of non-holonomic manifolds of many dimensions, which is an important branch of the modern differential geometry, is known to have been greatly furthered by the method of the so-called local coordinate systems, in particular, of non-holonomic coordinate systems defined by Schouten (1).

It is also known that there exists a relation between the differential geometry and the mechanics of systems of material points, namely, that the motion of a mechanical system may be interpreted as the motion of a point of unit mass in the configuration space of the system with the metric determined by the kinetic energy of the system.

In analytical mechanics, however, the method of non-holonomic local coordinates has received no wide application as yet, even for the investigation of non-holonomic mechanical systems.

Non-holonomic coordinates or «quasi-coordinates», as we shall call them, may prove to be of use not only in the study of non-holonomic motions, but in other problems as well.

The apparatus of quasi-coordinates in the mechanics was first built by L. Boltzmann (2) and G. Hamel (3), who gave their equations of motion of mechanical systems in quasi-coordinates.

In our previous paper (4) we reduced Boltzmann-Hamel's equations to the canonical form and constructed the Hamilton-Jacobi equation in quasi-coordinates.

In the present note we expose the fundamental property of this equation connected organically with the method of quasi-coordinates.

Consider a mechanical system of material points, the geometrical configuration of which is determined by n functions of time

$$q_1, q_2, \ldots, q_n \qquad (1)$$

which will be called true coordinates of the system.

Take the system of linear differential forms in q_μ

$$\omega_\rho = \sum_{\mu=1}^{n} \alpha_{\rho\mu} q'_\mu \quad (\rho = 1, 2, \ldots, n) \qquad (2)$$

where $\alpha_{\rho\mu}$ are functions of q_t.

The transformation (2) with the matrix $\| \alpha_{\rho\mu} \|$ will be called transformation (A).

Supposing the transformation (A) to be non-singular, we have the inverse transformation

$$q'_\mu = \sum_{\lambda=1}^{n} \beta_{\lambda\mu}\omega_\lambda \tag{3}$$

which will be called transformation (B).

The coefficients of these two transformations evidently satisfy the conditions

$$\sum_{\mu=1}^{n} \alpha_{\rho\mu}\beta_{\lambda\mu} = \delta_\rho^\lambda \tag{4}$$

where δ_ρ^λ is the Kronecker symbol, i. e.

$$\delta_\rho^\lambda = \begin{cases} 1 \text{ for } \lambda = \rho \\ 0 \text{ for } \lambda \neq \rho \end{cases}$$

Introducing the notation

$$\omega_\rho = \frac{d\pi_\rho}{dt}$$

we shall call π_ρ a holonomic coordinate, if the expression $\sum_{\mu=1}^{n}\alpha_{\rho\mu}dq_\mu$ is the perfect differential of this function π_ρ. Otherwise we shall call π_ρ a quasi-coordinate (non-holonomic coordinate).

The system of coordinates q_i will be called the basis of the system of quasi-coordinates.

Reducing the equalities (3) formally to

$$\frac{dq_\mu}{dt} = \sum_{\lambda=1}^{n} \beta_{\lambda\mu}\frac{d\pi_\lambda}{dt} = \sum_{\lambda=1}^{n} \frac{\partial q_\mu}{\partial \pi_\lambda}\frac{d\pi_\lambda}{dt}$$

we can define the differentiation of an arbitrary function $F(q_1, q_2, \ldots, q_n)$ with respect to a quasi-coordinate. Namely, by the derivative of F with respect to π_λ we mean the operator*

$$\left(\frac{\partial F}{\partial \pi_\rho}\right) = B_\rho(F) = \sum_{\mu=1}^{n} \frac{\partial F}{\partial q_\mu}\beta_{\rho\mu}. \tag{5}$$

Considering the scleronomic systems, denote by T the kinetic energy of the system and introduce the following group of variables, the so-called quasi-impulses

$$p_\lambda = \frac{\partial T}{\partial \omega_\lambda}. \tag{6}$$

The variables ω, p will be called canonical variables in quasi-coordinates.

Introduce now the Hamilton function H

$$H = T - U \tag{7}$$

where $U = U(q_i)$ is the function of the acting forces, and all ω_λ in T are expressed through p_λ from (6). We obtain the following canonical equations of motion of the dynamical system in quasi-coordinates

---

* To distinguish from the ordinary derivatives, those with respect to the quasi-coordinates are placed in parentheses.

$$\left.\begin{aligned} \omega_\lambda &= \frac{\partial H}{\partial p_\lambda} \\ \frac{\partial \pi_\lambda}{\partial t} &= -\left(\frac{\partial H}{\partial \pi_\lambda}\right) - \sum_{s=1}^{n}\sum_{r=1}^{n} \gamma^s_{r\lambda} p_s \frac{\partial H}{\partial p_r} \end{aligned}\right\} \tag{8}$$

where $\gamma^s_{r\lambda}$ are singular Ricci-Hamel's coefficients.

Then the Hamilton-Jacobi equation in quasi-coordinates will have the following form:

$$\frac{\partial V}{\partial t} + H\left[\left(\frac{\partial V}{\partial \pi_i}\right), q_i, t\right] = 0. \tag{9}$$

Having the complete integral $V(q_i, a_i, t)$ of the equation (9), we can obtain the general solution of the equations (8) from the equalities

$$\frac{\partial V}{\partial a_i} = b_i \qquad p_i = \left(\frac{\partial V}{\partial \pi_i}\right) \tag{10}$$

where a_i, b_i are constant.

2. Let us show that the Hamilton-Jacobi equation possesses the property of invariance with respect to the different systems of quasi-coordinates generated by the same basis. Namely, we shall prove that the coefficients of the equation (9) do not depend on $\alpha_{\rho\mu}$ and $\beta_{\lambda\mu}$.

In fact, to construct the left-hand side of the equation (9) we must express all the velocities q'_i in the function $H = T - U$ through the quasi-impulses and substitute the operators $B_\lambda(V)$ for the corresponding p_λ. These operations, however, must be carried out only for the kinetic energy which, in the case of scleronomic systems, has the form

$$T = {}^1/_2 \sum_{i,j} g_{ij} q'_i q'_j \tag{11}$$

According to (6) every p_λ can be expressed as follows:

$$p_\lambda = \frac{\partial T}{\partial \omega_\lambda} = \sum_{i=1}^{n} \frac{\partial T}{\partial q'_i} \frac{\partial q'_i}{\partial \omega_\lambda} = \sum_{i=1}^{n}\sum_{j=1}^{n} \beta'_{\lambda i} g_{ij} q'_j \tag{12}$$

By (4) we obtain from (12) the system of equalities

$$\sum_{i=1}^{n} g_{ij} q'_i = \sum_{i=1} \alpha_{ij} p_i \quad (j = 1, 2, \ldots, n) \tag{13}$$

that enable us to express q'_i through p_l

$$q'_j = \sum_{i=1}^{n}\sum_{\mu=1}^{n} G^{ij} \alpha_{\mu i} p_\mu \tag{14}$$

where G^{ij} denote the elements of the matrix $\| G^{ij} \|$ inverse to the matrix $\| g_{ij} \|$.

Replacing all q'_i by (14) and all p_μ by $B_\mu(V)$ in the expression of the kinetic energy and taking (4) into account, as well as the relations

$$\sum_{i=1}^{n} g_{ij} G^{i\lambda} = \delta^\lambda_j \tag{15}$$

we finally reduce the equation (9) to the form:

$$\frac{\partial V}{\partial t}+\frac{1}{2}\sum_{\lambda=1}^{n}\sum_{\mu=1}^{n}G^{\lambda\mu}\frac{\partial V}{\partial q_\lambda}\frac{\partial V}{\partial q_\mu}+\Phi(q_1, q_2, \ldots, q_n)=0 \qquad (16)$$

where $\Phi(q_1, q_2, \ldots, q_n)$ denotes the potential of the forces.

The equality (16) shows the invariance of the equation (9) with respect to all systems of quasi-coordinates, generated by linear differential transformations of the same basis.

On the theory of Lie groups the result obtained may be interpreted as follows.

The equalities (3) imply the following relations between the variations of the coordinates:

$$\delta q_\mu=\sum_{\lambda=1}^{n}\beta_{\lambda\mu}\delta\pi_\lambda. \qquad (17)$$

These equalities represent infinitesimal transformations; as to the $\beta_{\lambda\mu}$, they are coefficients of the infinitesimal operator ([5])

$$X_\lambda(F)=\sum_{\mu=1}^{n}\beta_{\lambda\mu}\frac{\partial F}{\partial q_\mu}.$$

The Poisson bracket applied to any pair of operators will be expressed linearly through all the operators, and $\gamma^s_{r\lambda}$ will be the coefficients in these linear combinations.

It is now possible to state the following theorem:

The equation (9), i. e. the Hamilton-Jacobi equation, for the given mechanical system rests invariant under infinitesimal transformations (17) of the coordinates of the system. Such an invariance takes place for the cases, when the infinitesimal transformations form a transitive group, i. e. when the coefficients $\gamma^s_{r\lambda}$ are constant, as well as for other cases, when $\gamma^s_{r\lambda}$ are functions of the variables q_i.

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PHYSIQUE MATHÉMATIQUE

SUR DEUX GROUPES FONDAMENTAUX DE POINTS SINGULIERS

Par I. S. KOUKLESS

(Présenté par S. L. Soboleff, de l'Académie, le 24.X.1943)

On sait que les conditions d'existence de vibrations périodiques et apériodiques (par exemple, celles qui s'éteignent) définies par l'équation différentielle

$$\frac{d^2x}{dt^2} = -\left[F\left(x, \frac{dx}{dt}\right)\right], \tag{1}$$

où $F(0,0)=0$, ne présentent rien d'autre que les conditions d'existence de centres, de foyers et de cycles limites pour l'équation différentielle

$$\frac{dy}{dt} = -\frac{F(x,y)}{y}. \tag{2}$$

Soit $F(x, y)=\lambda x+ay+f(x, y)$, où λ et a sont des constantes et la fonction $f(x, y)$ s'annulle à l'origine des coordonnées, ainsi que ses dérivées partielles. Alors, en suivant H. Poincaré [1], il est facile à montrer que l'origine sera: 1) un col si $\lambda<0$; 2) un semi-col — semi-noeud si $\lambda=0$, $a\neq 0$; 3) un noeud si $\lambda>0$, $|a|<2\sqrt{\lambda}$; 4) un foyer si $\lambda<0$, $0<|a|<2\sqrt{\lambda}$. Et dans le cas 5) $\lambda>0$, $a=0$ l'origine peut être ou bien un centre, ou bien un foyer pour lequel il existe un certain domaine qui l'entoure et qui ne contient pas de cycles limites, ou bien, enfin, un foyer près duquel se concentrent, comme près d'un point de condensation, les cycles limites.

Tous ces cas se divisent en deux groupes fondamentaux: on considère comme premier groupe celui qui contient tous les points singuliers tels que les caractéristiques passent par un tel point et y possèdent des tangentes déterminées (cas 1, 2 et 3); le second groupe contient tous les autres points singuliers (cas 4 et 5, c'est-à-dire foyer et centre). Il est bien évident qu'aux vibrations dans un voisinage aussi petit que l'on veut de l'origine, ils ne correspondent que des points du second groupe.

Dans tous les cas précédemment considérés on peut déterminer tout de suite si l'origine appartient au premier ou bien au second groupe. Mais dans le cas 6) $\lambda=0$, $a=0$ cette question devient plus compliquée et exige une étude supplémentaire. Supposons que le numérateur $F(x, y)$ du second membre de l'équation (2) est de la forme

$$F(x, y)=\lambda_n x^n+\lambda_{n+1}x^{n+1}+\lambda_{n+2}x^{n+2}+\ldots+ \\ +y(\eta_0+\eta_1 x+\eta_2 x^2+\ldots)+y^2\Phi(x, y), \tag{3}$$

où n est un entier positif, les quantités $\lambda_n, \lambda_{n+1}, \ldots, \eta_0, \eta_1, \eta_2, \ldots$ sont des constantes et la fonction $\Phi(x, y)$ est analytique au voisinage de l'origine.

Dans ces conditions le théorème suivant a lieu:

Théorème 1. *Pour que pour l'équation* (2) *l'origine soit un point singulier du second groupe, il faut et il suffit que:*

a) *le nombre n soit impair, $n=2k-1$ $(k=1, 2, 3, \ldots)$;*

b) *tous les coefficients η_i (pour $i<k-1$) soient nuls;*

c) *on ait l'inégalité* $\lambda_{2k-1} > 0$;

d) *on ait l'inégalité:* $|\eta_{k-1}| < 2\sqrt{k\lambda_{2k-1}}$.

Si l'une au moins des trois premières conditions n'est pas vérifiée, l'origine sera un col, ou bien un semi-col — semi-noeud, ou bien un noeud. Et si les conditions a), b) *et* c) *sont vérifiées, mais la condition* d) *tombe en défaut, alors l'origine sera un noeud.*

Exemple 1.

$$\frac{dy}{dx} = -\frac{\lambda_2 x^2 + \lambda_3 x^3 + \lambda_4 x^4 + \lambda_5 x^5 + y\varphi(x)}{y}, \tag{4}$$

où $\varphi(x)$ est une fonction analytique au voisinage de l'origine.

Pour que l'origine appartienne au second groupe, il est nécessaire, en vertu des conditions a) et b) du théorème 1, que l'on ait: $\lambda_2 = 0$ et ou bien 1) $\lambda_3 > 0$, ou bien 2) $\lambda_3 = \lambda_4 = 0$ et $\lambda_5 > 0$. Soit, par exemple, $\lambda_3 > 0$. Dans ce cas, en vertu des conditions c) et d) du théorème 1, nous devons avoir $\varphi(0) = 0$ et $|\varphi'(0)| < 2\sqrt{2\lambda_3}$ (dans le cas contraire l'origine appartient au groupe 1). Si ces conditions sont vérifiées, l'origine sera un foyer, ou bien un centre, et d'ailleurs en vertu du théorème 2 de la Note (²) dans notre cas l'origine ne peut être un centre que dans le cas et dans ce cas seulement où non seulement les conditions mentionnées sont vérifiées, mais on a d'ailleurs

$$\varphi(x) = \frac{d}{dx}\left[\Phi\left(x^2\sqrt{1 + \frac{4}{5}a_4 x + \frac{2}{3}a_5 x^2}\right)\right], \tag{5}$$

où Φ est une fonction quelconque analytique au voisinage de l'origine.

Si $\lambda_3 = \lambda_4 = 0$ et $\lambda_5 > 0$, alors pour que l'origine appartienne au second groupe, nous devons avoir: $\varphi(0) = \varphi'(0) = 0$; $|\varphi''(0)| < 4\sqrt{3\lambda_5}$ (et d'ailleurs dans ce cas l'origine sera un centre et non pas un foyer, si l'on a la condition supplémentaire $\varphi(x) = x\Phi(x^2)$, où Φ est une fonction analytique qui s'annulle avec x).

Si la dérivée du numérateur $F(x, y)$ du second membre de l'équation (2) possède la propriété: $\frac{\partial}{\partial x}F(0,0) \neq 0$, alors quand les coefficients de cette équation varient d'une manière continue, un noeud peut d'abord devenir un foyer et ensuite un centre, mais il ne peut devenir un centre sans intermédiaire. D'ailleurs, dans ce cas les caractéristiques au voisinage du centre ou du foyer ne changent jamais le sens dans lequel elles tournent autour du point singulier, c'est-à-dire elle vont toujours ou bien dans le sens des aiguilles d'une montre, ou bien dans le sens inverse. Remarquons que ces deux propriétés peuvent tomber en défaut si $\frac{\partial F(0,0)}{\partial x} = 0$, ainsi que l'on voit de l'exemple suivant.

Exemple 2.

$$\frac{dy}{dx} = -\left[x^2 + a_4 x^4 + a_5 x^5 + ky\,\frac{x + a_4 x^2 + a_5 x^3}{\sqrt{1 + \frac{4}{5}a_4 x + \frac{2}{3}a_5 x}}\right] : y \tag{4'}$$

[l'équation (4') est évidemment un cas particulier de l'équation (4) précédemment considérée]. Si $|k| \geqslant 2\sqrt{2}$, l'origine est un noeud pour notre équation, et si $|k| < 2\sqrt{2}$, il est un centre. Donc, dans ce cas quand le paramètre k varie d'une manière continue, un noeud devient subitement un centre.

D'ailleurs, pour $2 < k < 2\sqrt{2}$ dans un voisinage aussi petit que l'on veut de l'origine, les caractéristiques fermées changent le sens dans lequel elles tournent autour de l'origine (qui est un centre). En effet, la dérivée du rayon-vecteur ρ par rapport à l'angle polaire φ, c'est-à-dire

$$\frac{d\rho}{d\varphi} = y\,\frac{F(x, y) - x}{y^2 + xF(x, y)}, \tag{6}$$

change de signe quand on passe par l'infini dans un voisinage quelconque de l'origine, puisque le dénominateur du second membre de l'équation (6) est de la forme $y^2 + x^4 + kx^2 y + K(x, y)$; nous voyons que les trois premiers membres $y^2 + x^4 + kx^2 y$ de ce dénominateur présentent un polynôme homogène du second

degré en y et x^2 à racines réelles, et $K(x, y)$ contient seulement des membres d'ordre supérieur (par rapport aux variables y et x^2).

Considérons l'équation différentielle

$$\frac{dy}{dx} = \frac{f_0(x)\varphi_0(y) + f_1(x)\varphi_1(y) + \ldots + f_n(x)\varphi_n(y)}{y} \tag{7}$$

Soit $f_0(0) = 0$; $f_0'(0) < 0$; $\varphi_0(0) > 0$.

Théorème 2. *Si dans le voisinage de l'origine on a les égalités*

$$\frac{\varphi_k(y)}{\varphi_0(y)} = \Phi_k\left[\int_0^y \frac{t\,dt}{\varphi_0(t)}\right] \tag{8}$$

ou bien les égalités

$$\frac{f_k(x)}{f_0(x)} = \bar{\Phi}_k\left[\int_0^x f_0(x)\,dx\right] \tag{8'}$$

où les fonctions Φ_k sont univoques et Φ_k — des polynômes ($k = 1, 2, 3, \ldots$), alors non seulement l'origine, mais encore tous les autres points singuliers de l'équation (7) ne peuvent pas être des foyers. Et si dans l'égalité (8') toutes les fonctions $f_k(x)$ ($k = 1, 2, \ldots$) sont des polynômes, et parmi les fonctions $\bar{\Phi}_k$ il existe au moins une Φ_{k^*}, qui n'est pas un polynôme, alors au voisinage de l'une au moins des racines du polynôme $u^*(x) = \int_0^x f_0(\alpha)\,d\alpha$ l'égalité $\frac{f_{k^*}(x)}{f_0(x)} = \bar{\Phi}_{k^*}(u)$ tombe nécessairement en défaut. Dans ce cas l'origine n'est pas un foyer et les points singuliers de l'équation (4) autres que l'origine peuvent être non seulement des centres, des cols et des noeuds, mais aussi des foyers.

Exemple 3.

$$\frac{dy}{dx} = -\frac{(2x + 3a^3x^2)[1 + 2k(x^2 + ax^3)] + r(y)(2x + 3ax^2)[1 + 2l(x^2 + ax^3)]}{y},$$

où $r(y)$ est une fonction analytique et d'ailleurs $r(0) = 0$. Ici l'équation (8') a lieu pour les petites valeurs de x, mais pour $k \neq 0$ la fonction $\bar{\Phi}$ n'est pas un polynôme, mais une série infinie.

Si $1 + \frac{8k}{27a^2} < 0$ et $k \neq l$, d'un côté de l'origine il y aura un col, de l'autre un col et un foyer (l'origine est évidemment un centre).

Théorème 3. *Si la fonction $F(x, y)$ qui figure dans l'équation*

$$\frac{dy}{dx} = \frac{F(x, y)}{y} \tag{1'}$$

est un polynôme du degré n, et d'ailleurs pour cette équation les $\frac{n-1}{2}$ premières conditions pour un centre, si n est impair, ou bien $\frac{n-2}{2}$ premières conditions, si n est pair, sont vérifiées, alors on peut toujours choisir un polynôme $P(x, y)$ de degré $2n^2$ au plus qui ne contient que des termes de degré supérieur à n, et tel que pour $\frac{dy}{dx} = -\frac{F(x, y) + P(x, y)}{y}$ l'origine sera un centre.

Remarquons que dans son article «Wirbelpunkte und Strudelpunkte» [3] Frommer a seulement montré qu'on peut changer le signe d'un foyer en joignant des termes de degré supérieur à celui du polynôme $F(x, y)$, mais il ne démontre nulle part qu'on peut de cette manière transformer un foyer en un centre.

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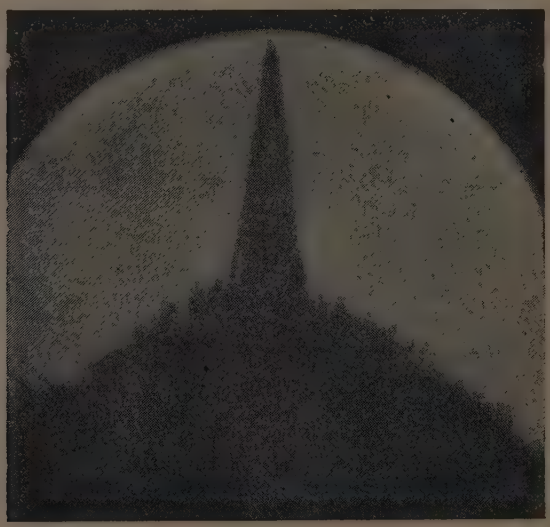
PHYSICS

DIRECTIONAL EFFECT OF EXPLOSION STUDIED BY OPTICAL METHOD

By F. A. KOROLEV and G. I. POKROVSKY

(Communicated by A. N. Kolmogoroff, Member of the Academy, 19.IX.1943)

The directional effect of explosions has found a wide application in this war in the form of the so-called «cumulative charges». The first to discover the cumulation phenomenon (directional effect) was Munroe, in 1888 (1), and of the later



Spark photography of a directed explosion («cumulative jet»)

workers we may mention Payman and Woodhead (2), who employed an optical method in studying it. Yet, notwithstanding the fact that this phenomenon has been known for a long time and is extensively used in practice, its experimental as well as theoretical side have been but poorly investigated.

In the experiments reported below which were run with small charges, the method of spark photography was used. The object investigated was the explosion of electrodetonator No. 8 with a copper shell. In its anterior part this detonator

had a spherical depression intended to produce the cumulation effect. For the illumination of the explosion a condensed spark of magnesium was used, fed from a special set-up designed to synchronize the explosion and illumination. By means of this apparatus a long series of photographs of the explosion was taken in the region of the cumulative jet. The evidence furnished by these photographs is that a distinct cumulative jet extends in the direction of the detonation axis in the shape of an acute cone, the apex of which moves with a very high speed. In the case of charges with a copper shell measurements gave a velocity of about 5000 m/sec. for distances 120 mm away from the cumulative depression of the detonator. Accordingly, much higher velocities—something of the order of 10000 m/sec.—may be expected in the vicinity of the charge.

It may also be inferred from these photographs that the speed of the not directed portions of the shock wave is approximately two times as low as that of the head of the cumulative jet. As the shell of the detonator takes upon itself a very considerable portion of the energy developed by the explosion, the speed of the cumulative jet should be higher in the case of charges with lighter shells (aluminium), and this assumption is corroborated by other measurements. What may further be inferred from the photographs is that as far away as at a distance of 10 to 15 charge calibers the explosive gases follow directly after the head of the jet, but afterwards gradually fall behind. The jet grows wider and wider to become practically transparent. In this phase it bears a strong similarity with a projectile flying at high velocity. This gives ground to presume that at this stage of development all energy of the jet is practically the kinetic energy of the directed beam (swarm) of fragments, whereas at earlier periods a considerable portion of it is with the explosion gases. It remains unclear for the present whether a strong shock wave is or is not present in the head of the cumulative jet.

From thoroughly studying the photographs of the head portion of the cumulative jet and from the records of this part taken by the method of Tepler it appears that a small portion of explosion products, as far away from the detonator as 100—200 mm, has a speed considerably exceeding that of the main mass near the detonator and reaching above ten thousands of metres in a second.

What has been attained by this investigation shows that similar experiments are possible with large charges. In this way it may be proved that the cumulation processes in explosions do or do not obey the similarity law; this well decide the question as to the feasibility of the use of models in studying these processes.

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PHYSICS

DESTRUCTION OF LATENT IMAGE OF α-PARTICLE TRACKS IN PHOTOGRAPHIC LAYER

By N. A. PERFILOV

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While a photographic plate with an emulsion able to register charge particles in the form of chains of developed grains is stored until it will be used in the experiment, it is recording tracks of α-particles which get into the layer in the natural way because of the radioactive contamination of the external medium. Moreover, it is continuously exposed to cosmic rays. The result is that at the moment it is taken for the experiments a series of phenomena is already impressed upon it in the form of a latent image which becomes apparent upon the development. To separate the results of the experiment from this natural background is not always easy and requires long and laborious working.

In the present paper is given a method for complete removal of the background before starting the experiment without appreciable reduction of the sensitivity of the emulsion to α-particles. The results obtained in these tests may also have an independent interest connected with the nature of the latent image.

As a result of the reaction between the charged particle and a grain of the photographic emulsion, the latter has part of its silver ions reduced to neutral ions which group together to form later the development centres. On this conception it seems possible to remove the silver atoms through the action of oxidizers and thus prevent the development of the respective grains. The problem may, indeed, be solved for such a density of the latent image as permits to follow the tracks of individual particles.

1. The Study of the Relationship between the Number of Tracks and the Concentration of Oxidizers when the Latter are Made to Act on a Photographic Layer before and after its Exposure to α-particles. All tests were run with fine-grained emulsions prepared according to a formula very near to that proposed by Zhdanov [1] for the registration of α-particles and protons. The thickness of the emulsion layer ranged from 70 to 100 μ.

As a source of α-particles in most cases served polonium precipitated electrolytically on a round silver plate 6 mm in diameter. The intensity of the preparation corresponded to the formation in the layer of 2×10^3 tracks of α-particles in a minute within a square millimiter of the surface.

The preliminary testing of a series of chemical compounds, as destroyers of the latent image, had shown that the most suitable of them were water solutions of CrO_3 (reaction with water gives chromic acid H_2CrO_4), $K_3Fe(CN)_6$ and $KMnO_4$. These compounds, if applied in certain concentrations, are able, as will be seen later, completely to destroy the latent image of tracks of charged particles without

destroying the gelatine layer or lowering its sensitivity to the further registration of α-particles.

One end of the photographic plate was exposed to the action of α-particles for four minutes and afterwards subjected to a 15 minutes bath in the solution of the tested compound at about 15° C (a bathing interval of 15 minutes ensures uniform action throughout the layer when it is 100 μ thick). After the bath the plate was washed during 40 minutes in distilled water which was changed time and again. Then followed dehydration by alcohol and ultimate drying in a current of heated air (up to 30°C). Now the other end of the plate was irradiated during the same interval of time as the first. The control and the test parts of the plate were simultaneously developed, fixed, washed, dried and examined under the microscope.

It may be inferred from this procedure that there were investigated at once the desensibilizing action of the test compounds on the photographic layer and their ability completely or partly, according to the concentration, to destroy the latent image.

In all tests the developer was a solution of the following composition: water, 440 cm³; sulphate (crystals), 30 g; hydroquinone, 6 g; potassium bromide, 2 g; potassium hydroxide, 2 g. Development for 16 minutes at 18° C.

The results of the experiments with α-particles are brought out by the curves of Fig. 1. On the ordinate axis is plotted the ratio of the number of α-particle tracks

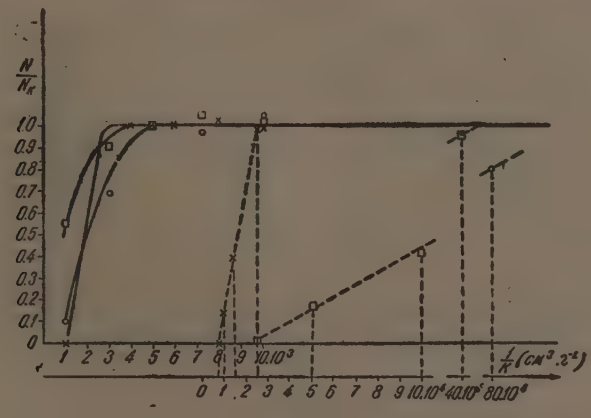


Fig. 1

—— Desinsibilizing action, - - - The action upon the latent image, × $H_2C_7O_4$, □ $KMnO_4$, o $K_3Fe(CN)_6$

on the test-plate (N) to that counted on an equal area of the control plate (N_k). The abscissae are inverse values of concentration, $\left(\frac{1}{k}\right)$, expressed in g/cm^{-3}. The curves drawn as full lines represent the variation of the desensibilizing action with concentration (exposure after bathing). The broken lines bring out the change in the number of α-particle tracks, that appeared on the plate upon its development when the latent image had been acted upon (exposure before bathing). In the latter case the values of the concentration are plotted on the lower axis.

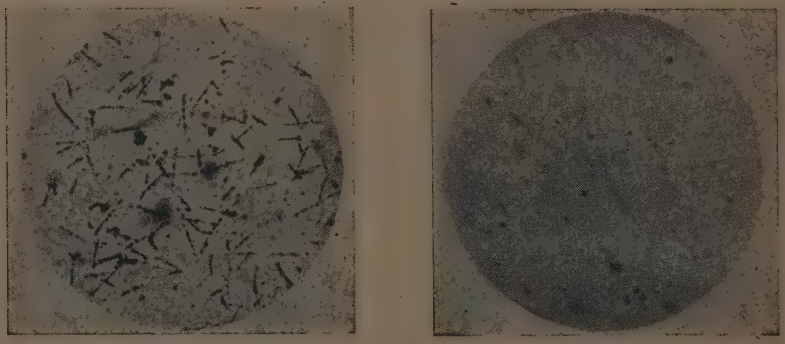
It may be seen from these curves that the results are essentially different, according as the treatment of the photographic plates precedes or follows their exposure to α-particles. Thus, in case the photographic layer is acted upon by chromic acid before the exposure, a concentration of $^1/_3 \times 10^{-3}$ g/cm³ has no effect on the recorded number of α-particles, whereas the action on the latent image reveals signs of particle tracks after the development only when the concentration has attained a value of $^1/_8 \times 10^{-3}$ g/cm³. When applied in a concentration higher than $^1/_8 \times 10^{-3}$, the chromic acid has a desensibilizing effect on the photogra-

phic layer with respect to α-particles. The influence of the treatment of a photographic layer with chromic acid before the exposure on the recording of α-particles has formerly been pointed out by Wambacher (2). It may, however, be remarked at this juncture that with a concentration that can render it insensitive to α-particles, the emulsion possibly ceases at all to respond to any known kind of radiation.

For the permanganate and ferricyanide of potassium the differences depending on whether the treatment is made before or after the exposure are still more apparent. In the case of these two substances the desensibilizing action stops at a concentration of $^1/_5 \times 10^{-3}$ g/cm³, while the action on the latent image brings out first signs of tracks at $^1/_{2 \cdot 5} \times 10^{-4}$ in the case of $KMnO_4$, at $^1/_4 \times 10^{-5}$ in the case of $K_3Fe(CN)_6$.

The conclusion to be drawn from these data is that by treating the photographic plate before the experiment by one of the above-mentioned substances applied in a not too high and not too low concentration we can, without impairing the sensitivity of the plate to α-particles, completely remove the background that may possibly have been formed in the photographic layer owing to the presence of α-particles and protons in the air, or as a result of the interaction between cosmic rays and the elements of the layer and its surrounding objects.

In order of uniformity of action across the thickness of the layer first comes the chromic acid, then the ferricyanide of potassium. The action of the permanganate



a *b*

Fig. 2

is to a great extent superficial. This is apparent from its action on the latent image when the limiting concentration is transgressed. The tracks of α-particles prove upon development to be cut on the side of the surface. It is largely for that reason that in the case of permanganate the ratio $\frac{N}{N_k}=1$ is attained, as seen from Fig. 1, by decreasing the concentration as much as 16 times the value at which the first signs of tracks α show up.

To illustrate the effect of annihilation of the latent image, photomicrographs are presented in Fig. 2. The photograph *a* has been taken from a plate exposed to α-particles after treatment with $K_3Fe(CN)_6$, concentration 1×10^{-4} g/cm³. Photograph *b* has been taken from that end of the same plate which was irradiated before the treatment. It illustrates the results of the action on the latent image. No tracks of α-particles are to be seen on the photograph.

2. Conservation in Time of Latent Image in Treated Plates. The latent image is known to lose in strength if the exposure and development are separated by a considerable interval of time. With respect to α-particles this phenomenon was investigated by Blau (3) and, more thoroughly, by Lauda (4). The results they have obtained are similar to those known for the visible light from a work by Hylan and Blair (5). The decrease of the density of the

latent image in time is connected with the process of recrystallization of silver bromide in the grain of the emulsion, which is influenced by the temperature and humidity of the air surrounding the photographic layer. *In vacuo* this process fails to take place. Among the factors accelerating it is the introduction in the layer of a desensibilizer which in the case of the above-mentioned authors was the yellow pinakryptol. I too have carried out an experiment in order to establish how the treatment of the photographic plate, which has the removal of the background for its purpose, may affect the preservation of the image newly formed in the layer. With this object in mind I subjected three plates to different treatment: one with chromic acid, concentration $^1/_5 \times 10^{-3}$ g/cm^3, the other two with $K_3Fe(CN)_6$ and $KMnO_4$, respectively; concentration 1×10^{-4}. Each plate was then divided in two and the halves irradiated with α-particles. Together with them two control plates bathed only in distilled water were irradiated. One plate from every pair was developed directly and the rest after a lapse of 30 days. The exposed plates were kept until development under ordinary conditions wrapped in black paper.

The results of counting the tracks of α-particles are presented in the table; T is the time interval between exposure and development. The data, allowing for a possible error of about 5 per cent, show that no acceleration is caused by the treatment when the latent image grows weaker in the course of time. This circumstance is of considerable importance when the preliminary treatment of the photographic plate described here is applied to long-term experiments.

Plates		Number of tracks, % to control	
		$T=0$	$T=30$ days
Control		100	81
Treated with	H_2CrO_4	100	84
	$K_3Fe(CN)_6$	100	80
	$KMnO_4$	100	78

3. Conclusions. Three oxidizers H_2CrO_4, $K_3Fe(CN)_6$ and $KMnO_4$ have been tested for their action on the latent image of polonium α-particles at a density of image corresponding to 8×10^3 tracks in 1 mm^2 of developed plate. It has been proved that, under certain conditions, the treatment of the photographic layer with these oxidizers can remove the latent image completely, and the sensitivity of the emulsion to α-particles will still retain its former value; nor does the process of weakening of the subsequently created image proceed at a higher rate in a treated plate.

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GEOPHYSICS

ON THE THEORY OF THERMAL PROSPECTING. ARTINSKIAN MASSIF AS REVEALED ON THE SLOPE OF GRAVITATION MAXIMUM

By S. S. KOVNER

(Communicated by O. J. Schmidt, Member of the Academy, 23.VII.1943)

The question as to the prospecting of Artinskian domes is a fundamental one for some of the regions of the Second Baku.

In a previous article (1) it has been shown that an Artinskian dome may be revealed for various typical profiles by comparing a corresponding calculation with the temperature measurements carried out in a given direction at a depth of 100—200 m.

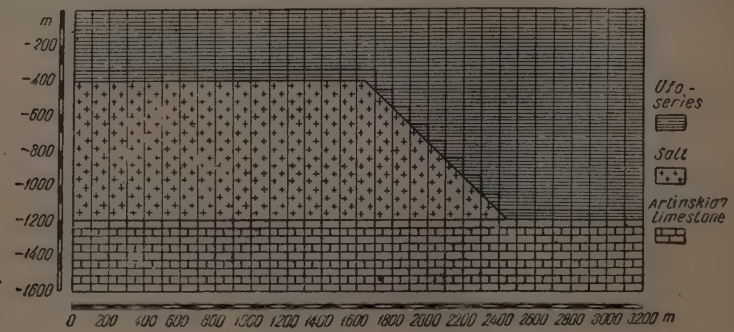

Fig. 1

In the present note the same method has been applied in order to analyse the case of an Artinskian massif lying on the slope of a gravitation maximum owing its origin to the Ufa deposits.

The profile is represented in Fig. 1. The Artinskian horizon is lying at a depth of 1200 m, being in the left part of the section, at a depth of 400—1200 m, overlain with a layer of Kungurian deposits, in our example, of salt rock. This Kungurian layer approaches the Artinskian horizon at an angle of 45°. In the left part of the section to a depth of 400 m from the Earth's surface, and in the right one, down to the depth of the Artinskian horizon, lies a layer of Ufa deposits, which is responsible for the gravitation maximum.

This profile is to be distinguished from that represented in Fig. 2 (bottom), the latter being characterized by an Artinskian dome lying on the slope of the gravitation maximum, the rest of dimensions, as well as the arrangement of the layers being otherwise the same.

As thermal constants we took the mean values of the coefficients of heat conductivity of the rocks, as obtained by measurements made by Kolesnikov (1) at Ishim-

bay with samples taken from depths corresponding to those referred to above. The value of the coefficient of heat conductivity of limestone, K_1, varies for the twelve samples from 0.00416 to 0.00518 $\frac{\text{cal.}}{\text{cm. sec. grad}}$, the mean value being $K_1 = 0.00469$.

For salt at corresponding depths, $K_2 = 0.00681$, which is the mean value for the coefficient of heat conductivity of the two samples measured (0.00685 and 0.00678).

For the Ufa red-stone the mean value of seven measured values within the interval between 0.00306 and 0.00405 equals $K_3 = 0.00352$.

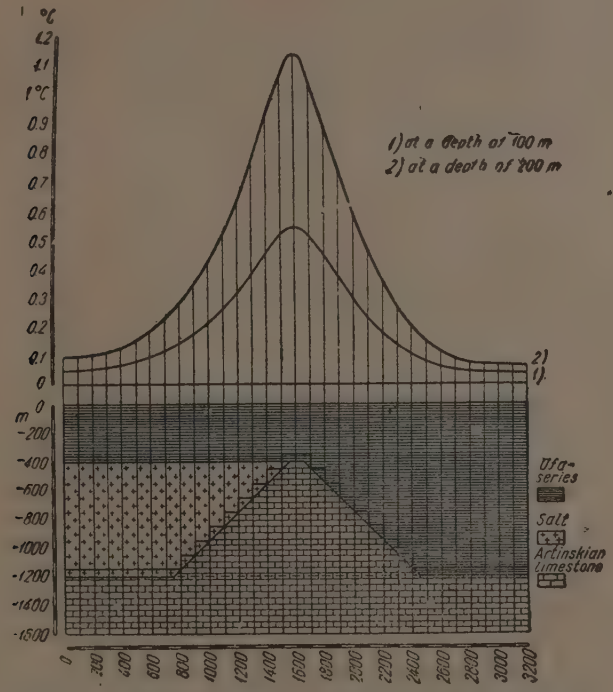

Fig. 2. Artinskian massif as revealed on the slope of the gravitation maximum. Position of Artinskian dome determined by calculatory method

With the aid of the method described in [1-3], i. e. by applying the method of nets to the Dirichlet-Neuman problem corresponding to our sections, we calculated the thermal field of the two profiles.

At a depth of 1600 m the temperature was supposed to be constant, equal to 48° C, which coresponds to a normal mean geothermal step of 3° C per 100 m; at the surface the mean annual temperature was assumed equal to zero.

To the depths of 100 and 200 m there corresponds a run of temperature which is shown in Fig. 3.

The differences between these two temperatures bear out the effect of the pure temperature anomaly which owes its origin to the presence of the dome. By comparing them with the profile investigated (Fig. 2, top) it may be seen, as well as in Figs. 1 and 3, that the curve of temperature differences repeats the outlines of the Artinskian dome: in the case of prospecting at a depth of 200 m, its maximum at-

tains 1.13° C, and at a depth of 100 m, 0.54° C, being situated above the top of the dome lying at a depth of 400 m below the surface of mean zero temperature.

We have thus shown that in principle these two cases can be separated from each

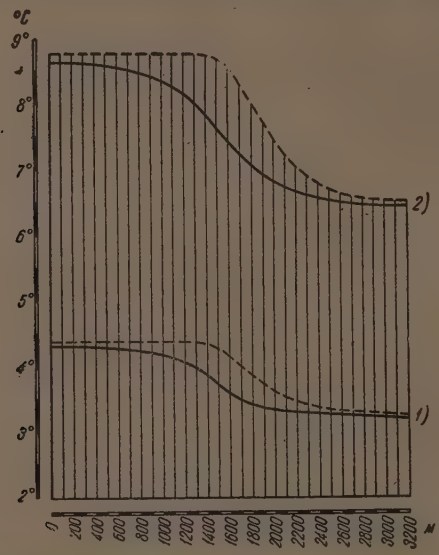

Fig. 3. Artinskian massif as revealed on the slope of the gravitation maximum. Thermal prospecting under natural conditions

—— In the presence of Artinskian dome, - - In the absence of Artinskian dome, *1*) at a depth of 100 m, *2*) at a depth of 200 m

other by means of thermal measurements, whereas their separation with the aid of gravitational, seismic or electrical methods involves difficulties.

We avail of this opportunity to express our thanks to engineer A. I. Khramoy who made us aware of the significances of the profile that has been investigated in the present problem.

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PHYSICAL CHEMISTRY

SOME MEASUREMENTS OF DETONATION VELOCITY OF METHYLNITRATE

By S. B. RATNER

(Communicated by N. N. Semenov, Member of the Academy, 7.VIII.1943)

1. Of the group of liquid nitric esters* the least investigated with regard to detonation properties is methylnitrate which is the most simple among them at the same time. As for the various inferences and generalizations available in literature and derived from the investigation of other members of the group — the nitroglycerine and nitroglycol, they are apt to raise many doubts which, however, may partly be removed by comparing the explosive properties of all liquid nitric esters.

What we have first to do along this line is to clear up the question whether all liquid nitric esters have like properties. In this respect a complete similarity between nitroglycerine and nitroglycol has recently been established by Chariton and the author([1]). They studied the propagation of the detonation flame in these two nitric esters photographically and proved in particular the existence in their case of two discrete groups of detonation velocities of about 7 and 1½ km/sec. Which of them takes place actually, depends upon the diameter and kind of the envelope of the charge and upon the character of the initiation; the heat of reaction corresponds to the higher velocities.

As the heat of decomposition of methylnitrate is near to that of nitroglycerine and nitroglycol, it was only natural to expect that its velocity of detonation would, under suitable conditions, likewise lie in the neighbourhood of 7 km/sec., although no such data were encountered in literature.

To put an example, more than half a century ago Berthelot ([2]) had found for the detonation rate of methylnitrate values ranging from 1217 to 2125 m/sec. which he himself characterized as lying far below those observed with compressed or powder-like explosives, viz. 6 to 8 km/sec.

2. I measured the rate of detonation of all liquid nitric esters. They were enclosed in a glass tube about half a metre long with walls 1 mm thick, and initiated by detonator No.8**. Measurements according to Dautrich *** gave the following results (see table).

It may be seen from these data that methylnitrate like other liquid nitric esters is remarkable for its values of detonation velocity falling into two discrete groups.

For the present this important property defies explanation and its existence can merely be stated. It is very likely, however, that we shall be able to account for it after it has been cleared up whether it is a peculiar feature of liquid nitric esters only, or occurs among a broader class of explosives, and if so, in which direction this class may be extended. From this point of view the question as to the rôle of

* I mean products of complete nitration of alcohols, having each of their carbon atoms linked with a hydroxyl.

** Contained explosives totalling 1.5 g in weight.

*** The description of this method will be found in any text-book on explosives.

Substance	Density, g/cm³	Diameter of charge, mm	Rate of detonation, km/sec.
Nitroglycerine	1.60	10	7.3
Nitroglycol	1.49	8	7.0
Methylnitrate	1.21	8	6.4
Methylnitrate	1.21	2.5	1.5

physical factors can be settled by a supplementary investigation of other liquid explosives and mixtures, and the problem of chemical factors, by studying solid nitric esters.

3. The results I obtained for methylnitrate and the analysis of literary data lead to the final conclusion that the explosive properties of all liquid nitric esters are similar, and in this light it is possible to discuss a number of generalizations made in literature. Two of them are considered below.

a) Naoum writes in his monograph ([3]): «Nitric esters having the same potential energy with nitroglycerine, but a lower viscosity—such are methylnitrate and nitroglycol, for instance—show a higher velocity of detonation». Yet this statement, as we have seen, is contrary to experience. As a matter of fact, density rather than viscosity is the factor determining the velocity of detonation.

That the detonation of methylnitrate may proceed with a high speed was unknown to Naoum, however, and so he compared only data on low velocity detonation.

But the latter does not correspond to the energy of the substance and is subject to the influence of a variety of external factors. Hence his erroneous conclusion.

b) The detonations of high velocity obtained with methylnitrate have proved its similarity with nitroglycerine in this respect, and left no room for any difference of opinion concerning the question of what should be considered as the true detonation velocity of nitroglycerine.

Let us quote some passages from an article by Gorst and Smirnov([4]). There, besides publishing their own data, the authors have made an attempt to review the preceding papers on the detonation of nitroglycerine. They write: «According to Stettbacher, the differences in the disruptive effect of nitroglycerine are probably due to the existence of two modifications». There is a statement of Stettbacher cited in their paper which runs as follows: «The higher the content of free nitroglycerine in the explosive jelly (gel), the closer its detonation velocity approaches that of pure nitroglycerine which is 2000 m/sec.». The reviewers obviously subscribe to this opinion, since they believe «those authors to be in error who appear to regard the detonation velocity of a pure nitroglycerine as firmly established and equal to 7—8 m/sec.».

And they concur with Dserschkowitsch and Andreew, to whose work they refer as including the most comprehensive evidence on the subject of detonation velocity and destructive power of pure nitroglycerine.

There ([5]) the theory of chemical isomeres is employed to account for «the anomalous value of destructive power in nitroglycerine. As a combination of two isomeres, nitroglycerine should naturally have their average explosive power. The labile form has a low brisance, while the stable form has a detonation speed of 9000 m/sec. But in a freshly prepared liquid nitroglycerine it is the labile form that predominates, and its destructive power being very low, the resulting speed of detonation is only 1200 m/sec.» (p. 402).

But the extreme simplicity of the formula of methylnitrate excludes the possibility of any isomerization whatsoever in the case of this compound.

Therefore the results obtained by me lead to the conclusion that the two groups of detonation in nitroglycerine are in no way connected with the above-mentioned factors, and that its true speed of detonation is somewhat above 7 km/sec.

Conclusions

1. A high velocity of detonation exceeding 6 km/sec. has been observed in methylnitrate, and there has been also reproduced a detonation of this compound with as low a velocity as 1.5 km/sec.

2. A complete analogy has been stated in the behaviour of all liquid nitric esters as regards their speed of detonation, and everyone of them showed the occurrence of two discrete groups of detonation velocities.

3. In spite of the assertions to the contrary available in literature, the velocity of detonation of liquid nitric esters has been shown to be independent of their viscosity, whereas it probably grows with density.

4. There has been brought to light the inconsistency of attempts to explain the differences in the explosive properties of nitroglycerine by the presence in it of two modifications.

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GEOLOGY

ON THE PROBLEM OF THE POST-PALAEOGENE UPLIFTS ON THE EASTERN SLOPE OF THE URALS

By B. P. KROTOV

(Communicated by A. N. Zavaritsky, Member of the Academy, 24.VIII.1943)

In the explanatory note to the geological map of the Urals on a scale 1 : 500 000 and in other papers by different authors there are indications as to the presence in the Urals of uplifts of meridional and latitudinal direction. Their position has not as yet been fixed with sufficient accuracy. Further inferences along this line can be made, in the author's opinion, from a study of the absolute level of the Palaeogene marine deposits and of the nontronite weathering crust of the pre-Jurassic time on ultra-basic rocks.

The surface of the Palaeozoic on the eastern slope of the Urals, left uncovered by the Upper Cretaceous and the Palaeogene sea advancing from the east, presented a weathering surface which was being shaped during the early part of the Mesozoic, the areas of the development of ultra-basic rocks having been covered with a nontronite weathering crust. It may be assumed that the surface of planation at different places of the eastern slope of the Urals originated approximately at a similar absolute height. The Upper Cretaceous and the Palaeogene marine transgression were caused by a subsidence of the Urals gradually spreading from east to west. As a result of the subsidence, the Upper Cretaceous and Palaeogene seas inundated and covered with gaizes the eastern part of the region of the Mesozoic planation surface.

In the following an attempt is made to analyse the problem as to the change in the relief of the surface of the Urals after the Palaeogene transgression of the sea.

In considering the altitude marks of the planation surface at the beginning of the Mesozoic and the coastal belt of the Palaeogene in different parts of the range, a very considerable and at the same time irregular variation of their absolute height is observed along the eastern slope of the Urals.

The Palaeogene gaizes of the coastal part of the sea between Burmantovo and N. Lyalya at present occur at a height of 129 — 140 m. In the space between N. Lyalya and the Uy river the Palaeogene gaizes gradually rise to a height of 155, 165 and 200 m; at the Argayash region, to 240—280 m; and at the Bredov region, to 380 m. Similarly, the average absolute height of the Palaeozoic rock belt varies, too, this belt having been reduced to a peneplain during the Mesozoic. The near-shore parts of this surface, i. e. the portions near the presumable shore of the Palaeogene sea, have now the following average altitude marks: (1) 800—200 m west of Burmantovo; (2) 200—250 m west of Ivdel; (3) 200—300 m between Serovo and N. Lyalya; (4) 150—250 m at the latitude of the Tura river; (5) 200—300 m in the eastern half and 400—450 m in the western half, flooded by the Palaeogene sea over an area between the Tura river and Ufaley; (6) 230—325 m along the latitude of Argayash and Karabash; (7) 300—400 m in the eastern part, formerly submerged by the sea, and 400—800 m in the western part over an area between lat. 54° and 53°40′ N; (8) 250—350 m in the eastern part flooded by the sea during the Palaeogene, and 350—1100 m in the western part over the space between 53°40′ and 51° N.

In comparing the altitude marks of the near-shore deposits of the Palaeogene with those of the near-shore part of the planation surface of the Mesozoic time, the following regularities may be established: (1) on the eastern slope of the Urals in the interval between lat. 51° and 62° N a number of alternating uplifts and depressions of a latitudinal direction are distinguished, namely: (a) the southern limb of the uplift north of lat. 60° N; (b) the Tura downwarping approximately at the latitude of the Tura river and the Tavda river (lat. 59—60° N); (c) the Taghil-Ufaley uplift (between lat. 59 and 56° N); (d) the Ufaley-Cheliabinsk downwarping, i. e. between lat. 55—56° N; (e) the Uy or Troitzk-Upper Ufaley uplift approximately along lat. 54° N; (f) the northern limb of the Orsk downwarping (lat. 54—51° N).

On the map of the Urals it may distinctly be seen that in the downwarpings the Palaeogene deposits closely approach the axial part of the range, while within the uplifts they recede rather far eastward. Owing to the large general elevation of the southern part of the Urals, in the Ufaley-Cheliabinsk downwarping and the northern limb of the Orsk downwarping the Palaeogene deposits lie at a considerably greater absolute height than in the Tura downwarping, viz. 240 m in the first, 360—400 m in the second, and 129—140 m in the Tura downwarping. The great elevation of the southern part of the Urals caused there an intenser erosion of the Palaeogene deposits which at present form in the downwarpings only a number of detached fragments lying on the planation surface of the Mesozoic time.

Similar to the Palaeogene, the rocks of the sedimentary-volcanogenic series S_2—D_1 have also an insignificant absolute height in the downwarpings; they are projecting in the eastern part of the Mesozoic planation surface.

The western part of the planation surface constituted by rocks of the S_2—D_1 sedimentary-volcanogenic series, with intrusive bodies of acid and ultra-basic rocks, is raised to a relatively considerable height.

The areas of uplifts are characterized, in the first place, by a relatively large width of the belt of the planation surface and a total absence of the Palaeogene cover. The eastern half of the planation surface of the Mesozoic time formed by the belt of D_2—C_1 rocks with intrusions of acid and ultra-basic rocks, in the recent past covered by marine deposits of the Palaeogene, shows absolute heights declining from 300 to 200 m in a direction from west to east. The western part of the planation surface formed by the sedimentary-volcanogenic S_2—D_1 series, broken by intrusive bodies of acid and ultra-basic rocks, is characterized by an absolute height of 400—550 m on the average, the average height increasing southward.

But aside from the unequal elevation of the Palaeogene and of the different parts of the belt of Siluro-Devonian rocks composing the western part of the Mesozoic planation surface, the unequal degree of the elevation of different structural members composing the latter is also definitely pronounced. This fact has been already recorded by a number of writers.

The different elevation of the Urals at different places accounts for the cases of the appearance of younger deposits at some places throughout the belt of the sedimentary-volcanogenic rocks of the S_2—D_1 series which in the literature have been explained by local pitches of the axes of folds. Thus, E. A. Kuznetzov (1941) noted the pitch of the greenstone belt in the Northern Urals along riv. Sosva, where the S_2—D_1 deposits give way to D_2—D_3, or even to the Tournaisian. In the Southern Urals A. V. Khabakov (1941) noted a southward pitch of the Irendyk anticline. On the map accompanying the paper the replacement of Silurian rocks by Devonian rocks (Lower, Middle and locally Upper Devonian) is quite distinctly shown. But in addition to the places indicated, where the presence of younger deposits within the belt of the sedimentary-volcanogenic rocks of S_2—D_1 has been established (these facts having been duly interpreted), on the geological map of the Urals on 1 : 500 000 scale there are also analogous places in the region south of Miass and in the region of the Atlyan river. Here, on the continuation of the same belt of S_2—D_1 rocks, instead of these younger deposits—D_3, C_1^1, C_1^2—are exposed. According to G. A. Mirlin and E. S. Dobrokhotova (1940), the deposits of the Lower Carboniferous (C_1^1 and C_1^2) are located in the troughs of synclinal folds. E. S. Dob-

rokhotova points out that in the valley of the Atlyan river the axes of the synclinal folds of the Vasilyevsky mine pitch northward.

As it is seen, the alternation of latitudinal depressions and elevations of the surface observed on the eastern slope of the Urals is related to a parallel pitch and rise of the axes of synclinal and anticlinal folds of the rocks of the sedimentary-volcanogenic S_2—D_1 series at the places of these depressions and elevations. This shows that the depressions and elevations in the eastern slope of the Urals are not due to erosion or abrasion processes but have been caused by tectonic agencies.

Along with this, in the areas of lowerings of the axes of synclinal and anticlinal sediments also a disappearance of bedded intrusions of ultrabasic rocks is noted, which upon approaching the area of pitch are gradually thinning out, diminishing in number and finally wedge out completely. This fact shows that local pitches of the axes of synclinal and anticlinal folds in the S_2—D_1 belt occurred as early as during the Palaeozoic; the upper portions of the intrusions of ultra-basic rocks being located at different absolute heights and at the places of a pitch of the axes of the folds of the Palaeozoic, the ultra-basic rocks remained unexposed by erosion and are absent on the planation surface of the beginning of the Mesozoic. At these places instead of the S_2—D_1 rocks there are found younger deposits, covering the former, of D_2, D_3, C_1 and sometimes even C_2 age.

In the post-Palaeogene time during the general elevation of the Urals, a reduced rate of elevation of axes of folds of the Palaeozoic occurred at the places of ancient pitches, as a result of which marine Upper Cretaceous and Palaeogene deposits have been still preserved here, while at other places on the continuation of the folds they have been already eroded.

The differences in the rate of elevation at different places of the eastern slope of the Urals, related to the differences in its tectonic structure have determined both the present relief of the surface of the eastern slope of the Urals, and the direction of flow of all the rivers flowing down the eastern slope of the Urals.

At the same time, the differential elevation of different parts of the Urals in the post-Palaeogene time caused also differences in the absolute height of the present position of the ancient early Mesozoic planation surface and of the ultra-basic rocks projecting above it and covered with a nontronite weathering crust. Indeed, in the eastern part of the eastern slope of the Urals the nontronite weathering crust of ultra-basic rocks is at present located at an absolute height of 200—250 m; and in the western part, at a height of 370—420 m.

Moreover, within the western half of the eastern slope of the Urals, according to whether it is located within areas with a synclinal or an anticlinal structure, the hontronite weathering crust of ultra-basic rocks is found at a different absolute height, this difference in height sometimes exceeding 100 m. Thus, e. g., the nontronite weathering crust on the anticlinal range of Ural-tau in the Khalilovo region (Aidarbak, Tuyetash) is located at an absolute height of 370—400 m, and in the Aktyubinsk region (Batamsha, Kempirsay) at a height of 400—500 m.

On the other hand, in regions with a synclinal structure it lies lower: at the Orlovskoye deposit, at 250 m; at the Akkerman deposit, at 240—280 m; in the region of Mustafina, at 260 m.

The knowledge of the regularities governing the position of the nontronite weathering crust of ultra-basic rocks on the eastern slope of the Urals in its different zones and the fact that it is found absent within latitudinal pitches on the eastern slope, is of great importance when searching for new nickel-ore deposits.

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GEOLOGY

ON THE HYDROTHERMAL FORMATIONS OF THE KOROBKOV AREA OF THE KURSK MAGNETIC ANOMALY

By E. K. LAZARENKO

(Communicated by A. E. Fersman, Member of the Academy, 13.V.1943)

Within the quartzites and the rocks of the Kursk Magnetic Anomaly (KMA), accompanying the former, hydrothermal formations are extensively developed. However, they have not yet been subjected to investigation. This paper contains the preliminary results of the investigations carried out by the author in the Korobkov area.

The Korobkov area of KMA is characterized by the development of pre-Cambrian, Devonian, Jurassic, Cretaceous, Tertiary and post-Tertiary formations.

The pre-Cambrian deposits are represented by metamorphic rocks; the other deposits, by sedimentary rocks, the average thickness of which is about 116 m.

The sedimentary beds rest on the uneven eroded surface of the pre-Cambrian which here, by analogy with the better studied Schigrov region, is subdivided into three divisions: (1) the upper, represented by crystalline limestones, calcareo-micaceous schists and grey phyllite-like sericite-biotite schists; (2) the medium, consisting of thin-banded magnetite quartzites with thin intercalations of magnetite amphibole and magnetite-biotite schists; and (3) the lower, composed of mica schists with intercalations of magnetite quartzites and fine-grained biotite gneisses, and medium-grained biotite and conglomerate-like gneisses.

Within the Korobkov area proper the rocks of the middle division are developed. Their thickness attains 200 m.

From the structural standpoint the country is characterized by the development of a great synclinorium with a raised core in the region of Stary Oskol. Within the synclinorium in the Korobkov area the rocks are strongly dislocated, and are nearly overturned having a general strike 330°NW—150° SE with an angle of dip about 80° to the north-east.

The synclinorium has moreover reflected the folding of the second and still larger order, expressed in various folds (most frequently isoclinal ones) passing into plications.

Along with folds, fractures are also observed. According to manifestation and morphology, the folds may be subdivided into two groups: microfolds and macrofolds.

The microfolding is represented mainly by microplications, among which the keel-shaped microfolds form the predominant type.

The macrofolds are mainly isoclinal with a dip of the limbs and the axial planes conformable to the bedding.

As to the fractures, their variety within the Korobkov area may be reduced to two principal groups:

1) fractures concordant with the enclosing rocks;

2) fractures cutting the enclosing rocks at different angles.

Fractures concordant with the enclosing rocks are represented by two types: those conformable to the enclosing rocks both along the dip and along the strike, and those conformable to the enclosing rocks along the strike but dipping to the opposite side (cutting along the dip).

Fractures concordant with the enclosing rocks both along the dip and along the strike are in most cases fractures of a schistosity of rocks composed mainly of acicular and foliated minerals. In quartzites these fractures are genetically related to schistose intercalations.

Fractures cutting the enclosing rocks are in the majority of cases represented by flat and horizontal fractures, although along with such also diagonal ones are observed; among these particular mention should be made of fractures perpendicular to the bedding. Along the fractures of the second type, in some cases microdisplacements are observed.

Fractures of both the first and the second type were the main channel ways or the circulation of hydrothermal solutions and at places for the concentration

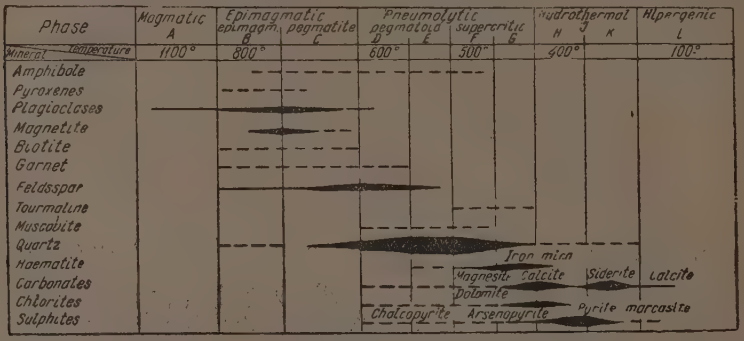

Fig. 1. Geochemical diagram of hydrothermal formations of the Korobkov area of KMA

of hydrothermal deposits, the most favourable being the fractures conformable to the enclosing rocks, of the nature of schistosity fractures.

The thickness of the hydrothermal deposits varies within a wide range, from microscopic size to 10—20 cm. Sometimes veins are encountered reaching a thickness of 1 m in swells.

The principal forms in which hydrothermal deposits are encountered are lens-like veins and veinlets; along with these also modes of rock impregnations with hydrothemal formations are developed. Veins and veinlets with a thickness persistent even over a small distance are very rare. Quartz veins and veinlets carrying micaceous haematite are commonly met in the ladder form. In this case the haematite fills a series of small parallel fissures breaking the quartz vein.

From their mineralogical composition, the hydrothermal rocks are represented by the following main types: (1) quartz, (2) pyrite, (3) micaceous haematite, (4) carbonate, (5) feldspar and (6) mixed, in which, along with the minerals listed, other minerals also take part. Out of the types listed, the most widely distributed are the quartz, carbonate and pyrite types.

The mineralogical composition of the hydrothermal deposits of the Korobkov area of KMA may be shown by the following table in which the minerals are arranged in the approximative order of their quantitative predominance (see table).

The sequence of segregation of the minerals and their geochemical characters are shown in the accompanying graph prepared after A. E. Fersman (Fig. 1).

Chemical and spectrum analyses of the hydrothermal minerals of the Korobkov area of KMA have revealed the presence in them of chemical elements given in the geochemical table, also prepared after A. E. Fersman (Fig. 2).

Analyses for such elements as Fe, P, Sb, Pt, Ta, Nb, W, In, Bi, Mo, Cd, Zr and Tl have yielded negative results.

Main minerals	Rather widely distributed minerals	Rare minerals
Quartz, siderite, pyrite, calcite, feldspars	Chlorite, muscovite, magnetite, micaceous haematite, garnet, biotite, amphibole	Magnesite, dolomite, tourmaline, marcasite, chalcopyrite, arsenopyrite, pyroxenes

In order to settle the question as to the age of the hydrothermal deposits, attention should be paid to the problems of structure.

On the basis of preliminary investigations it may be considered that the formation of the general structure of the Korobkov area of KMA took place in two phases. The first phase was that of a general folding of rocks which had previously had

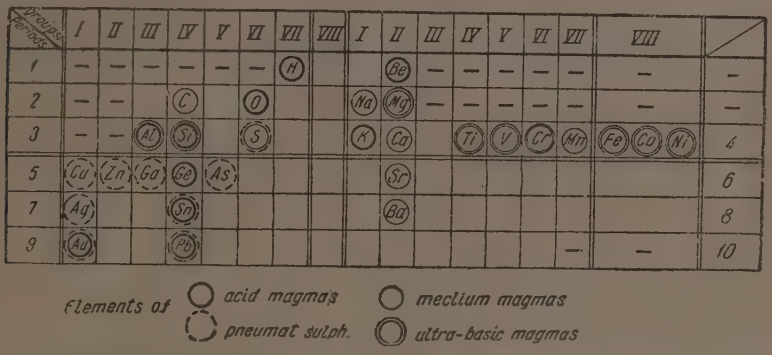

Fig. 2. Geochemical table of elements of the hydrothermal formations of the Korobkov area of KMA

a horizontal attitude; genetically related to this phase was the formation of small folds and plications, on the one hand, and the formation of erosions, on the other. These phenomena should be considered as a repercussion of a great tectonic phase which determined the general aspect of the Korobkov area.

During the very last stages of the first phase there occurred an intrusion of magmatic rocks. Sufficient evidence of this is furnished by the findings of calcitized aplite-like granite made in shaft No. 1 while driving the pump chamber. Here the granite in the form of a thin veinlet (up to 10 cm thick) lies conformably to the bedding of the quartzites over a distance of about 1. 5 m, filling schistosity fractures in rocks ready by this time.

The aplite-like granite and the hydrothermal deposits seem to be of the same age and are products of differentiation of the same bulk magma lying at a considerably greater depth. The hydrothermal deposits like the aplitic granite, used fractures existing by the time of their formation.

The igneous rocks found in the Korobkov area of KMA in the southern portion of the area (hole No. 216) as porphyry-like granite bear distinct traces of pressure, which justified the assumption that jointly with the other it has been subjected to tectonic processes belonging to the second phase.

To the second phase repeated small fractures seem to be related which are particularly well marked in the arch portions of small folds and plications and are found to be filled with quartz and micaceous haematite.

During the second tectonic phase no hydrothermal deposits seem to have been formed. The quartz and micaceous haematite veinlets filling repeated fractures are a product of recrystallization of magnetite quartzites without any supply of material.

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GEOLOGY

ON THE AGE OF THE EPOCH OF COMPLETED MINERALIZATION IN THE SARALA GOLD-ORE DEPOSIT (SIBERIA, KUZNETSK ALATAU)

By V. K. MONICH

(Communicated by W. A. Obruchev, Member of the Academy, 29.VIII.1943)

Within the Sarala ore field distinguished among the gold-ore areas of the Kuznetsk Alatau by the large size of its ore veins, a great dyke intrusion of proterobases is developed ([2], [5]).

Numerous dykes of proterobases striking in a north-western direction (320—350° NW) dissect the ore field of the Sarala mines into narrow bands-segments, break the gold-ore veins and occasionally displace their broken parts. The thickness of the proterobase dykes varies from fractions of a meter to 30 m. The total volume of the dyke masses constitutes about 20 to 25 per cent of the volume of the rocks of the ore field, attaining in separate nodes of consolidation 40 to 50 per cent of the rock mass.

Such a great number of dykes highly complicates the structure of the deposit and affects its prospecting and operating. Hence it should be recognized that the dyke intrusion of proterobases plays an exceedingly important part in the structure of the Sarala ore field, being responsible for the principal and most numerous disturbances of the gold-ore veins.

At the same time the intrusion plays also an exceedingly important part in the mineralization of the gold-ore veins. Novoselov ([5], [6]), who made a detailed study of the Sarala deposits, was the first to note the active part played by proterobase magma in the gold-ore vein mineralization. The appearance of the dykes had produced a strong heating of the wall rocks, especially at the contact with flat dipping dykes. As a result, metamorphic transformations of the minerals of the ore veins are noted. Cubanite appears at the expense of chalcopyrite, pyrite is converted to pyrrhotite; a certain redistribution of gold also takes place, with an enrichment with the metamorphosed areas. Along with this, a distinct additional stage of mineralization is displayed in the deposit, which seems to be genetically related to the intrusion of proterobases being the closing stage in the minerogenesis of the deposit. During this stage of mineralization rather widely distributed minerals of gold-ore veins are formed, such as epidote, albite, actinolite, pyrrhotite, chalcopyrite, sphalerite and probably partly gold, too.

From what has been said it follows that a precise determination of the geological age of the proterobase intrusion will make it possible to determine the upper age limit of the gold-ore mineralization of the region and the age of the main disturbances of the deposit. The geological observations in the region do not furnish any precise answer to this question, and at present there is a diversity of opinion as to the age of the proterobase intrusion.

In 1917 M. A. Ussov, Member of the Academy, advanced the opinion that the proterobases are the leading channels of the Devonian effusives developed

east of the ore area (1). This view was supported in 1928 by Bulynnikov (2). In 1933 Novoselov[4] discovered south of the Sarala mine a crossing of red sandstones and conglomerates by proterobase dykes which he assigned from the lithological peculiarities to the Devonian (3). On these grounds Novoselov considered the proterobases to be post-Devonian formations. But Ussov in his well-known cumulative paper (4) expressed the assumption that the red deposits of Sarala are of Cambrian age and considered the proterobases as analogues of the Upper Silurian gabbro-syenites.

In the subsequent papers by Novoselov (5,6) on the basis of petrographic analogies it is suggested that with regard to age the proterobases approach to the traps of the Kuznetsk basin and were formed during several phases of the Mesozoic cycle of tectogenesis.

At present more precise data on this problem are available.

Geological observations have established the Devonian age of the red beds located east of the Sarala ore field. In the sandstones of this formation along the Sarala-Iyus river the author discovered vegetable remains determined by Prof. V. A. Khakhlov as *Asteroxylon elberfeldense* Kraus et Weil.; from its flora, the age of the formation is determined within the range of the Lower and the lower part of the Middle Devonian. Thus, a post-Devonian age of proterobases has been quite definitely established.

In order to determine the upper limit of the geological age, at the Radium Institute of the Academy of Sciences of the USSR a determination of the absolute age of the proterobases has been carried out.

A monolith of proterobase of the third generation of Novoselov (5,6) was taken for examination. The monolith was taken after a blasting of the face at the Grauman adit of the Ivanov mine. The specimen is a dark-grey fully-crystalline medium-grained porphyry-like rock with numerous tabular segregations of grey plagioclase (2 to 4 mm in size) in a fine-grained mass, consisting of plagioclase, augite, hornblende and ore minerals.

Under the microscope larger prisms of a cloudy somewhat saussuritized andesine No. 38—42 are distinguished.

The groundmass is a gabbro-ophitic fine-grained aggregate with an average size of the grains 0.2—0.3 mm, consisting of small prisms of plagioclase of the same composition and isometric grains of augite with a slight violet-grey coloration. The augite is grown around with a fringe of a greenish-brown hornblende which in rare cases passes to an emerald-green ore along the edges. Of the accessory minerals a small amount of apatite, leucoxenized sphene, pyrite and more marked quantities of magnetite and ilmenite are observed.

Of the secondary minerals, along with saussurite, separate foliae of colourless chlorite are observed. As compared to the type composition of proterobases after Rosenbusch, the Sarala proterobases are distinguished by a very small development of biotite.

The chemical analysis of the specimen yielded the following results (in per cent):

SiO_2 —49.85	MgO —3.35
TiO_2 — 2.33	CaO —7.48
Al_2O_3—15.48	Na_2O—3.68
Fe_2O_3— 5.83	K_2O—1.28
FeO — 8.31	P_2O_5—0.17
MnO — 0.04	Loss on ignition—2.74
	H_2O—0.16

According to the peculiarities of their chemical composition, the rocks approach some typical proterobases, being, however, distinguished from these by a lower magnesium and calcium content [(7), p. 400].

The loss on ignition is rather high, but taking into consideration the presence of pyrite, chlorite and saussurite minerals, it may be assumed that it is not due to the weathering of rocks. The conditions under which the monolith was taken at a considerable depth, directly upon blasting, also eliminate the influence of weather-

ing. The determination of the geological age was carried out by the helium method at the Radium Institute of the Academy of Sciences of the USSR by Prof. I. E. Starik and Prof. E. K. Gerling. The following results were obtained:

Specimen	U, g/g	Th, g/g	He, ml/g
Proterobase of the third generation, Grauman adit of the Ivanov mine of the Sarala group	1×10^{-6}	2.5×10^{-6}	6.3×10^{-6}

The calculation of the absolute geological age made by the simplified formula of A. Holmes gives a value of 33 million years, which after Holmes' scale [9] corresponds to the middle of the Tertiary.

The data obtained determine only the upper age limit of the proterobase intrusion, since when applied to rocks and many minerals the helium method usually gives a somewhat undervaluated age, owing to a more or less considerable loss of helium by the specimen, the value of which may be approximately estimated only by a special study [Gerling's criterion [8]].

At present we are far from knowing all the factors governing the loss of helium by minerals. It is believed that the loss of helium in rocks depends to a certain extent on the degree of freshness of the specimen, on the possibility of its metamorphization in the past (heating) and on some peculiarities of its structure and composition. Thus, e. g., acid and coarse-grained rocks show a higher loss of helium than fine-grained and basic rocks.

From this standpoint the quality of the specimen analysed may be recognized satisfactory, and there is no reason to suppose a particularly high loss of helium.

According to Gerling, the usual losses of helium in basic rocks make up 30—70 per cent. If the maximum average value of the loss be considered, the age of the proterobase intrusion should be assigned to the Lower Cretaceous or to the Upper Jurassic. It is scarcely probable that the Sarala proterobases refer to the Palaeozoic.

Consequently, the data of the radio-geological analysis of the Sarala proterobases, along with some geological data, point to the young age of this peculiar and characteristic magnetic formation of the Kuznetsk Alatau. They give also a more or less precise determination of the geological age of the closing epoch of mineralization and the time of the main disturbances in the Sarala gold-ore deposit.

In conclusion, the author wishes to thank Prof. I. E. Starik and E. K. Gerling who have kindly investigated the monoliths.

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PLANT PHYSIOLOGY

AGE VARIATIONS IN THE COLLOID-CHEMICAL PROPERTIES OF PROTOPLASM OF VEGETABLE CELLS

II. VARIATIONS IN PERMEABILITY AND VISCOSITY IN THE LEAF CELLS OF BROAD-BEANS AND OATS

By N. A. MAXIMOV, Corresponding Member of the Academy, and L. V. MOZHAEVA

In our preceding note (1) we have described our experiments with cells of different age of resting reserve organs of plants, viz. with cells of onion scales and leaves of cabbage heads. These experiments showed that the youngest cells are endowed with an extremely high degree of permeability which drops rather abruptly as the cell grows older; in very old cells, however, the permeability is observed to increase again. Unlike this, the viscosity of the protoplasm is found to be the lowest in the youngest cells, and to increase with age, which points to the plasma colloids becoming less hydrophilous. By the end of the cell development, no reduction in the viscosity of its protoplasm is observed again.

We found it necessary to check up these observations and to substantiate them by studying objects of a different kind, viz. leaves of various age taken from fully vigorous shoots of plants. In such shoots age variations could be traced both in leaves of the same node, the determination being made at various terms of vegetation, and in cells of leaves from different nodes by making the determinations at the same term, not only their individual, but also their general age (2) being different.

As experimental plants we chose the broad-bean, *Vicia faba*, and the oats «Pobeda» which were grown in earthern pots from May to October 1941. As in the first case, permeability was determined from the variation of the specific electroconductivity of the water in which the leaves had been immersed for 3 hours. The age variations of protoplasm viscosity were determined by the method of centrifuging (3); we recorded the rate of displacement of chloroplasts in the subepidermic cells of the petioles of leaves of *Vicia faba*, when rotated at a speed of 1500 revolutions per minute.

Let us describe one of our experiments with leaves of *Vicia faba* (Table 1), which illustrates the variations in permeability according to the node of leaves and their individual age. The order of the leaves is counted from below.

From this table it may be seen that young leaves of every node which just start developing, show a higher permeability which decreases appreciably and rather rapidly according as they become older. The rate of this decrease is well illustrated, for example, by the data of the first test, on May 5. We had here leaves of different age because some of the plants sprouted sooner than the other, and their leaves of the first node were by one or two days older. This small age difference told, however, markedly upon the permeability, having reduced the specific electroconductivity from 84 to 54. In the subsequent the permeability kept during a rather considerable

Table 1

Exosmosis of Electrolytes ($K^* \times 10^5$) from Leaves of *Vicia faba*

Date of sampling	Age of leaves and development stage of plants	Node 1	Node 3	Node 5	Node 7
5.V	Leaves 2 days old	84	—	—	—
	Leaves 3 days old	54	—	—	—
9.V	Appearance of 4th pair of leaves; 3rd pair of				
16.V	leaves 2—3 days old	26	133	—	—
	Appearance of 6th pair of leaves; 5th pair of				
23.V	leaves 2—3 days old	38	27	54	—
	Appearance of 8th pair of leaves; 7th pair of				
2.VI	leaves 2—3 days old	36	28	27	51
	Flower-bud formation	37	38	39	48
17.VI	Blossoming	37	45	42	47
8.VII	Fruit formation, first leaves grow yellow	86	52	55	—
22.VII	Leaves yellow and their edges dry	—	—	65	46

* K, specific electroconductivity.

period at about the same level; towards the time of fruit-formation, however, and of a pronounced ageing of the leaves (yellowing), there was an appreciable increase in permeability again. Similar results have been obtained also in a number of other experiments.

Below data are tabulated which were obtained from another experiment with *Vicia faba* (Table 2) and oats (Table 3). The figures tabulated are the means from 5—7 parallel determinations.

Table 2

Exosmosis of Electrolytes ($K \times 10^5$) from Leaves of *Vicia faba*

Date of sampling	Age of leaves	Node 1	Node 2	Node 3
16.IX	2—3 days	202	—	—
19.IX	5—6 days	111	—	—
2.X	3rd pair; 3—4 days	73	86	104
21.X	Leaves of 1st and 2nd node become yellow	284	103	174

Table 3

Exosmosis of Electrolytes from Oat Leaves of the Bottom Node

Date of sampling	Age of leaves and development stage of plants	Specific electro-conductivity ($K \times 10^5$)
4.IX	Leaves 2—3 days old, scarcely beginning to develop	491
6.IX	Leaves 4—5 days old	422
16.IX	The 3rd leaf starts unrolling	193
22.IX	The 4th leaf starts unrolling	91
13.X	The leaves begin to yellow, especially at the tips	322
21.X	The leaves are strongly yellowed	693

In these experiments, too, particularly in those with oats, according as the leaves grow older, the permeability of the protoplasm of their cells may clearly be seen to decrease at first, after which there is a sharp increase in permeability.

General ageing, i. e. increase in the leaf nodes, is also accompanied with reduced permeability which by the end of vegetation is obscured by an earlier ageing of the bottom leaves. The data obtained are in perfect agreement with what has been observed by us [1] with resting leaves in onion bulbs and cabbage heads. But the permeability in ageing leaves is more clearly pronounced in growing shoots because of the sharper age differences. By comparing all these data, the general conclusion may be arrived at that the ability of vegetable cells to retain electrolytes, as observed in the course of ontogeny, assumes the course of a single-peak curve which entirely corresponds to the age-curve plotted by Krenke [2]. Therefore permeability (i. e. a magnitude inverse to this ability) proves to be higher both in the youngest and in the oldest leaves, while in leaves of medium age it is reduced. To use Krenke's expression, every newly formed leaf is thus «temporarily rejuvenated» with respect to the permeability of its protoplasm, which at the beginning increases once more. However, with every new leaf node the maximum ability to keep the electrolytes gradually decreases again, i. e. the minimum permeability grows higher and higher, which is due to the influence of a general ageing of the leaves of the upper nodes.

Age variations similar to these have been observed by us in the permeability within a single oat leaf. As in oat the leaves grow by their bases (like in the rest of monocotyledons), at the beginning of leaf development the highest permeability is observed at the basic, i. e. the youngest part of the leaf, decreasing towards the tip, i. e. the maturest part of the leaf. Adult leaves display, however, a different picture, viz. now it is the middle part of the leaf that shows the lowest permeability which increases both towards the youngest base and the oldest tip of the leaf. According as the leaf is ageing, the picture changes again, and the distribution of permeability becomes inverse to that observed in young leaves: near its base the leaf is found to be the least permeable, in its middle part the permeability increases, to attain its maximum at the tip which is ready to die away. In old leaves therefore we observe a gradual increase of permeability from the base to the tip. Thus, the typical single-peak curve of permeability variation along the leaf may be observed in middle age leaves only.

Age variations in the viscosity of the protoplasm were investigated by us by the method of centrifuging only in cells of leaf petioles in *Vicia faba*. The results are tabulated below.

Table 4

Time Necessary for Displacement of Plastids in Cells of Petioles of *Vicia faba* (in minutes)

Date of sampling	Development stage of plants	Node			
		1	5	10	15
7.V	3rd pair of leaves beginning to develop . . .	3	—	—	—
12.V.	4th » » » » » »	10	—	—	—
20.V	7th » » » » » »	20	5	—	—
9.VI	Flowering	15	10	5	—
1.VII	Ripening of fruit	20	15	5	5

The above data show that along with the ageing of the cells, there is necessary a longer centrifuging in order to bring about a displacement of plastids; this should be taken to mean that the viscosity of the protoplasm grew higher. At the same time the protoplasm of the cells in every new leaf that appears on the stem proves to be reduced at the start of its development, which points to a «rejuvenation» of those cells. We observed no viscosity reduction in ageing cells: this change in the properties of the protoplasm, which is associated with a reduction of its hydrophily, seems to be irreversible.

The observations which make the subject of the present and of the preceding article [1] go clearly to confirm that such fundamental colloid-chemical properties of the protoplasm of vegetable cells, as its viscosity and permeability, are subject to regular variation in the course of their ontogenetic development. Namely, the ageing process in every cell is characterized first by a reduction and next by a new increase of its protoplasm permeability, and by an irreversible increase of its viscosity. When new organs are going to be formed (leaves in our experiments), there is a sharply pronounced rejuvenation of the protoplasm of the cells, both its permeability and viscosity being again restituted at the level which had been observed in their predecessor-organs at the beginning of their development. Thus, the results obtained do perfectly fit within the scheme of Krenke's [2] theory of the cyclicity of ageing and rejuvenation during the ontogeny, which was built largely on morphological material. They may therefore be taken to confirm this theory on a material of physiological nature.

At the same time, the age variations observed by us in the permeability of the protoplasm may be considered also from the standpoint of their bearing on the age variations in the metabolic processes taking place in the cells. Namely, the high permeability of the young cell protoplasm guarantees for their rapid supply with the nutrient substances necessary for their intense growth. On the other hand, the new increase in the permeability of those cells that approach the end of their ontogenetic development, facilitates the translocation of the substance accumulated by them to the younger organs of the plant, and their reutilization by these. Naturally enough, the direction of the flow of nutrient substances, which is in the former case towards the cell and in the latter out of it, is underlain by other physiological properties, e. g., according to Oparin's theory [4], by a change in the trend of the activity of enzymes. Age variations of the latter also deserve more detailed investigation.

The increased permeability of the protoplasm as due to temporary dehydration of the cells (wilting), which has been observed by Maximov and Soykina [5], is also in full accord with the results obtained by us: in a number of studies [6,7], it has been found earlier that insufficient water supply results in an earlier ageing of the plants, while profuse and regular watering contributes to their rejuvenation, impeding the process of ageing.

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